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Feasibility of synthetic fuels in renewable energy systems

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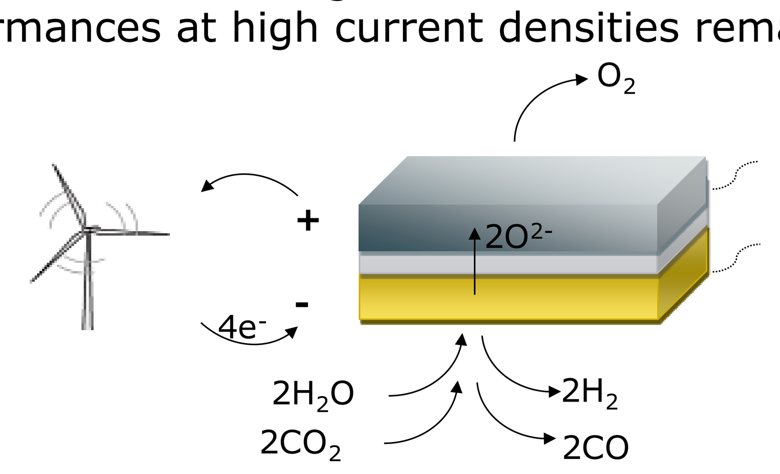
The transport sector is the only sector in which there have been no significant renewable energy penetrations and it is heavily dependent on oil with rapid growth in the last decades. Moreover, it is challenging to obviate the oil dependence due to the wide variety of modes and needs in the sector. Nowadays, biofuels are proposed as one of the main options for replacing fossil fuels in the transport sector, along with electricity. The main reasons for avoiding the direct usage of biomass in the transport sector, i.e. producing biomass derived fuels, are land use shortage, limited biomass availability, interference with food supplies, and other impacts on environment and biosphere. Hence, it is essential to do a detailed analysis of the transport sector in order to match the demand and to meet the criteria of a 100% renewable energy system in 2050.

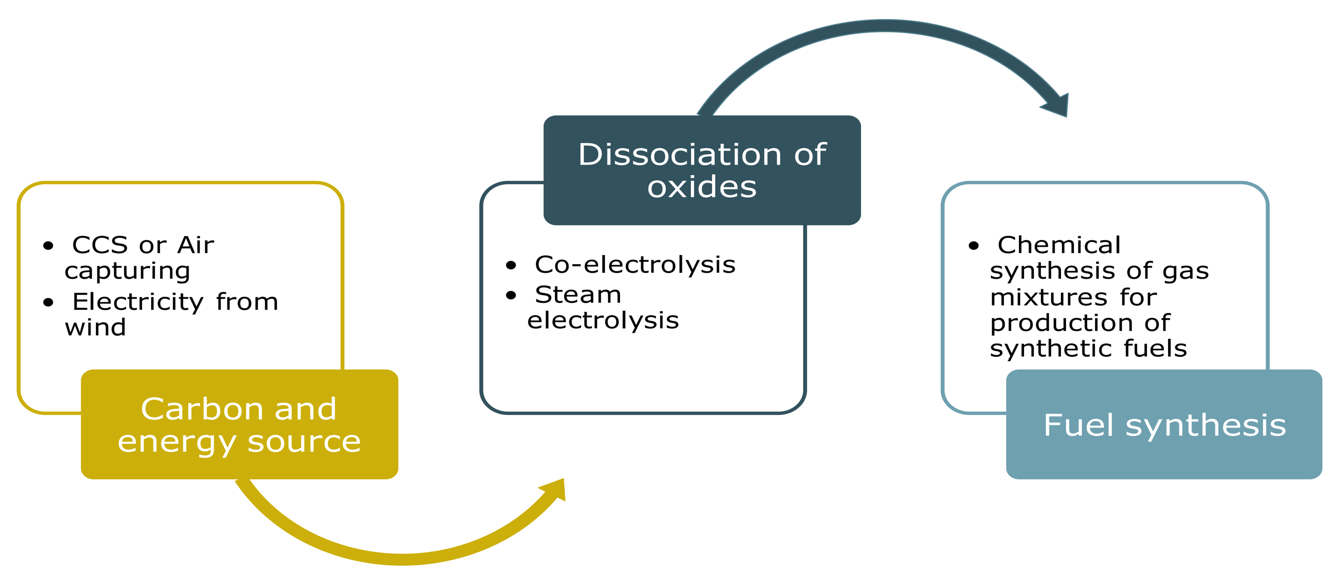
SOLID OXIDE ELECTROLYSER CELLS

The advantages of solid oxide electrolyser cells are the potential for great fuel production rates at high efficiency, low material costs and the possibility of co-electrolysis of H_2O and CO_2. Solid oxide electrolyte conducts oxide ions which cannot be done with other types of cell. High operating temperature and high pressure, which provides further efficiency improvement, enables the integration of catalysis of the synthetic gas to synthetic fuel.
The main disadvantage of SOECs is the durability of the cell - durable performances at high current densities remain to be proven.



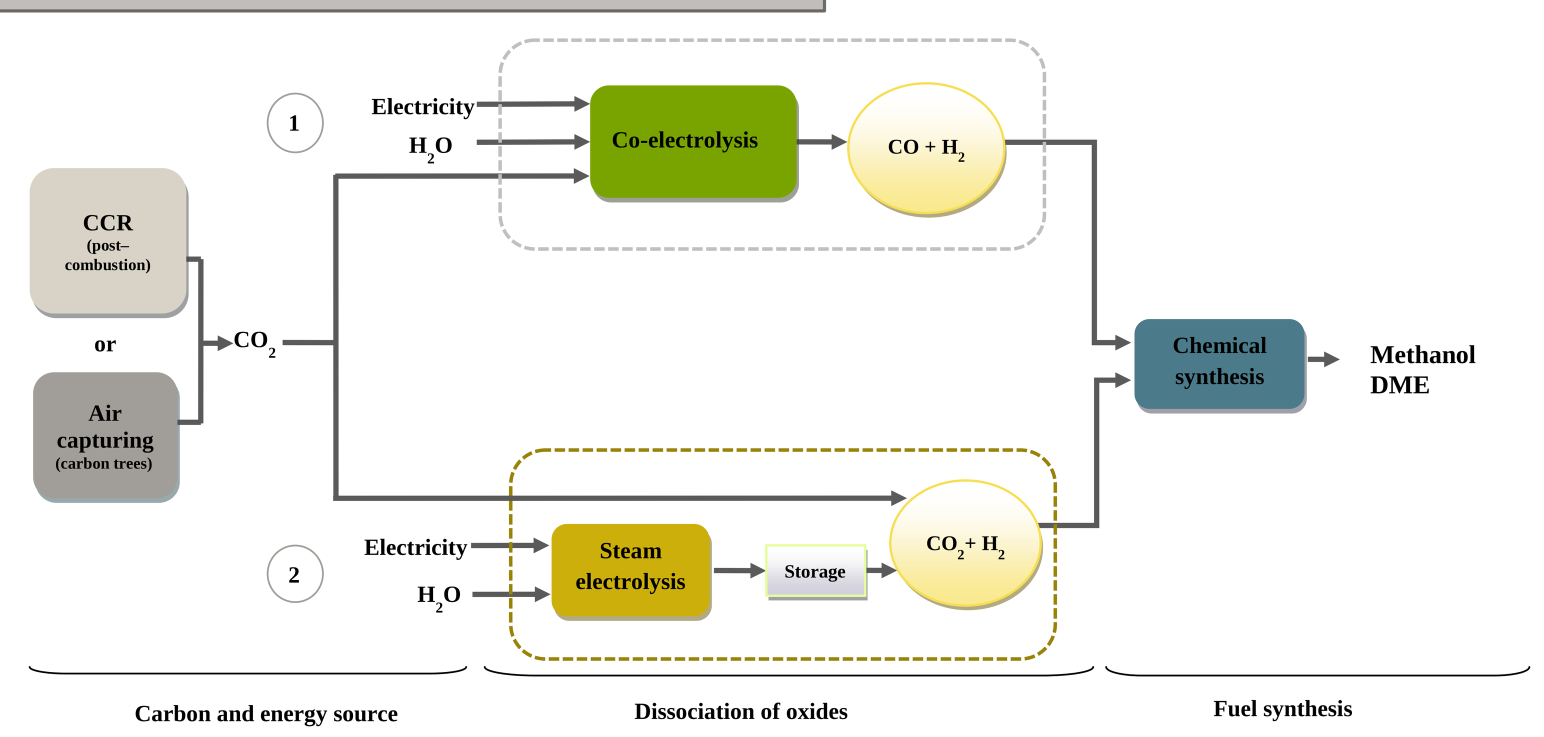
Porous positive electrode (anode)
$2O^{2-} \rightarrow O_2 + 4e^-$
Porous negative electrode (cathode)
$2H_2O + 4e^- \rightarrow 2H_2 + 2O^{2-}$
$2CO_2 + 4e^- \rightarrow 2CO + 2O^{2-}$
Net cell reactions
$2H_2O$ + electricity $\rightarrow 2H_2 + O_2$
$2CO_2$ + electricity $\rightarrow 2CO + O_2$

PRODUCTION CYCLE OF SYNTHETIC FUELS



Two carbon sources are proposed - CCR from energy sector or air capturing as a promising future technology. Pathways are divided into three steps. Energy source drives dissociation of oxides, either H_2O or both H_2O and CO_2, which results in gas mixtures that are in the last step catalyzed to fuels.

PATHWAYS FOR PRODUCING SYNTHETIC FUELS

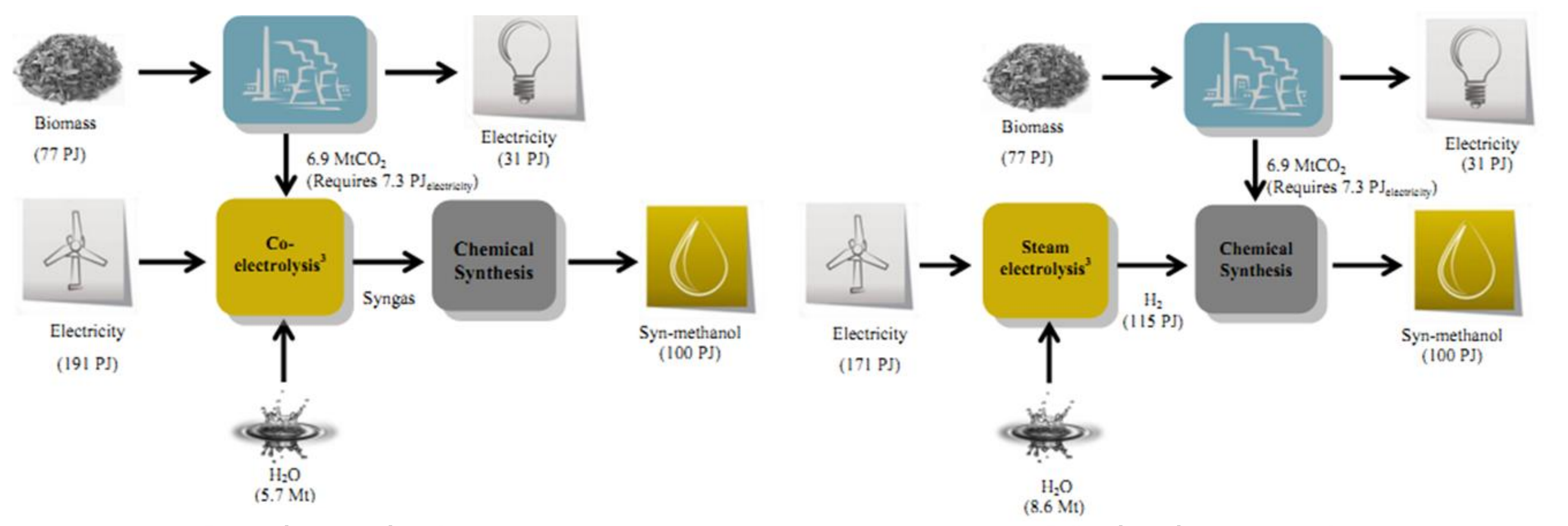


Both pathways for producing synthetic fuels exclude direct biomass input for fuel production. However, these pathways are in strong connection with power and heat sector that uses biomass

CONCLUSION

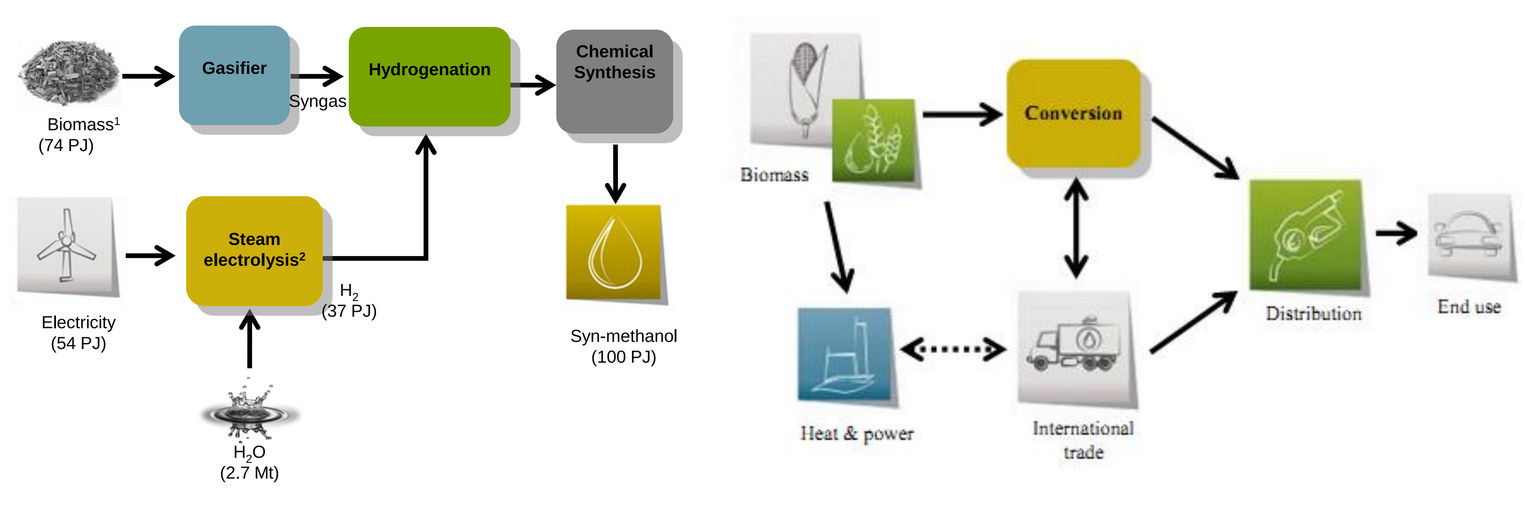
Costs of synthetic fuel scenarios are more expensive, but biomass savings associated with this make the additional costs worthwhile due to the scarcity of biomass for the energy system. With feasible technological development and mass production of the Solid Oxide Electrolyser Cells, synthetic fuels could be competitive and have market advantage over biomass derived fuels based on their supply related issues, land use shortage, limited biomass resources, etc.

PATHWAYS FOR PRODUCING SYNTETIC FUELS AND ALTERNATIVES



Co-electrolysis *CO_2 hydrogenation*

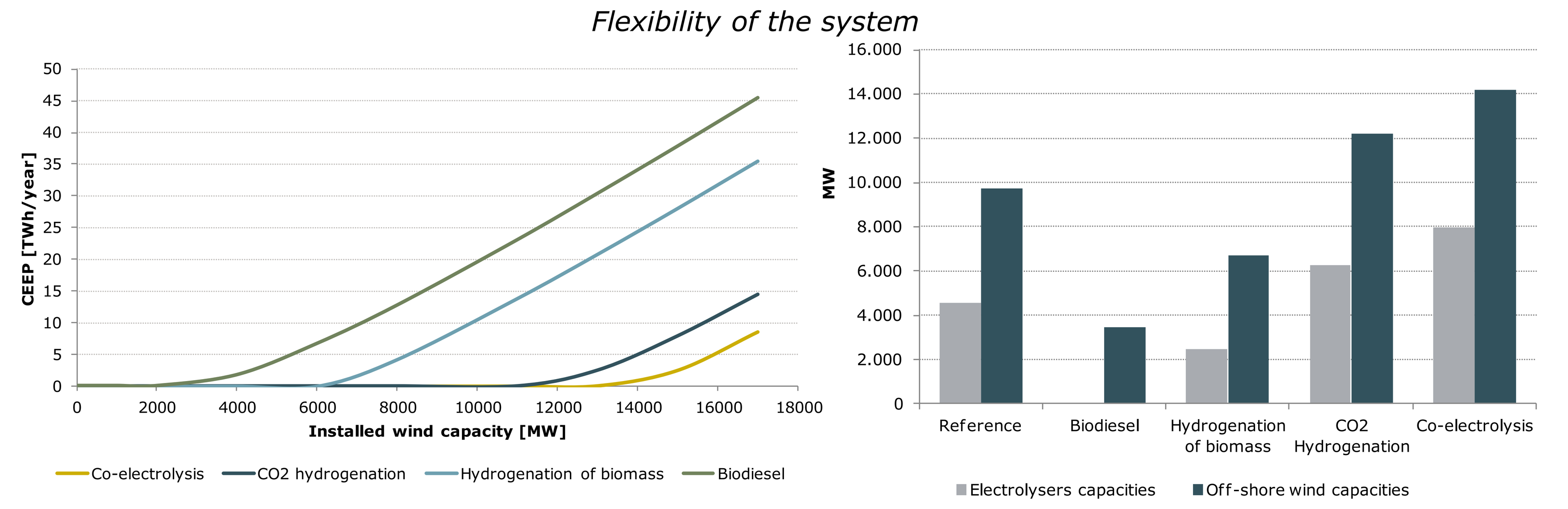
Pathways	Description
Co-electrolysis	Production of liquid fuel by a combined process of steam and CO_2 electrolysis. Carbon source is CCR cycle from biomass power plant. No direct biomass usage.
CO_2 Hydrogenation	Hydrogenation of CO_2 involves steam electrolysis and afterwards the reaction of hydrogen with recycled CO_2 from biomass power plant. No direct biomass usage.
Hydrogenation of biomass	Hydrogenation of biomass involves gasifying the biomass into a syngas and then reacting hydrogen from steam electrolysis with this gas
Conventional Biodiesel	Conventional biodiesel production by transesterification of vegetable oils and fats



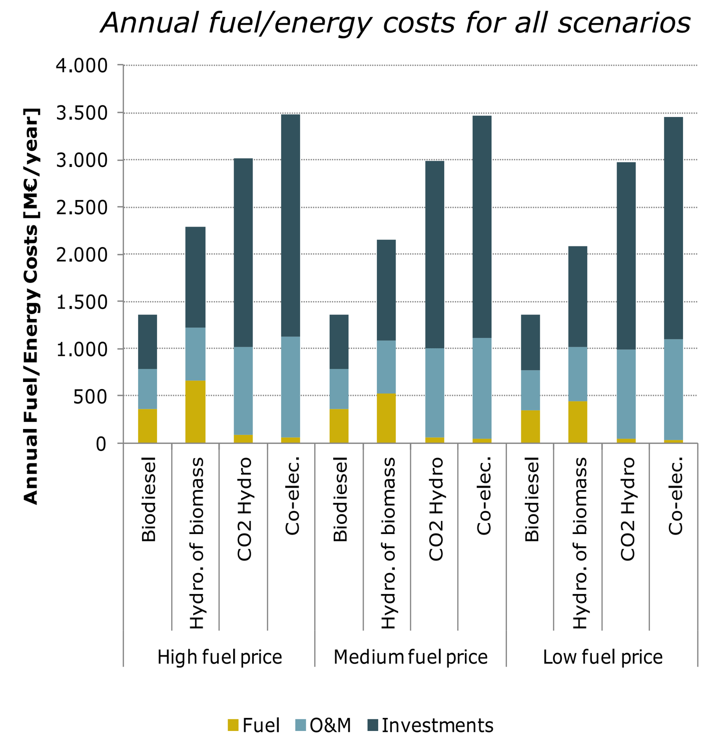
Hydrogenation of biomass *Conventional biodiesel*

ENERGY SYSTEM MODELLING AND RESULTS

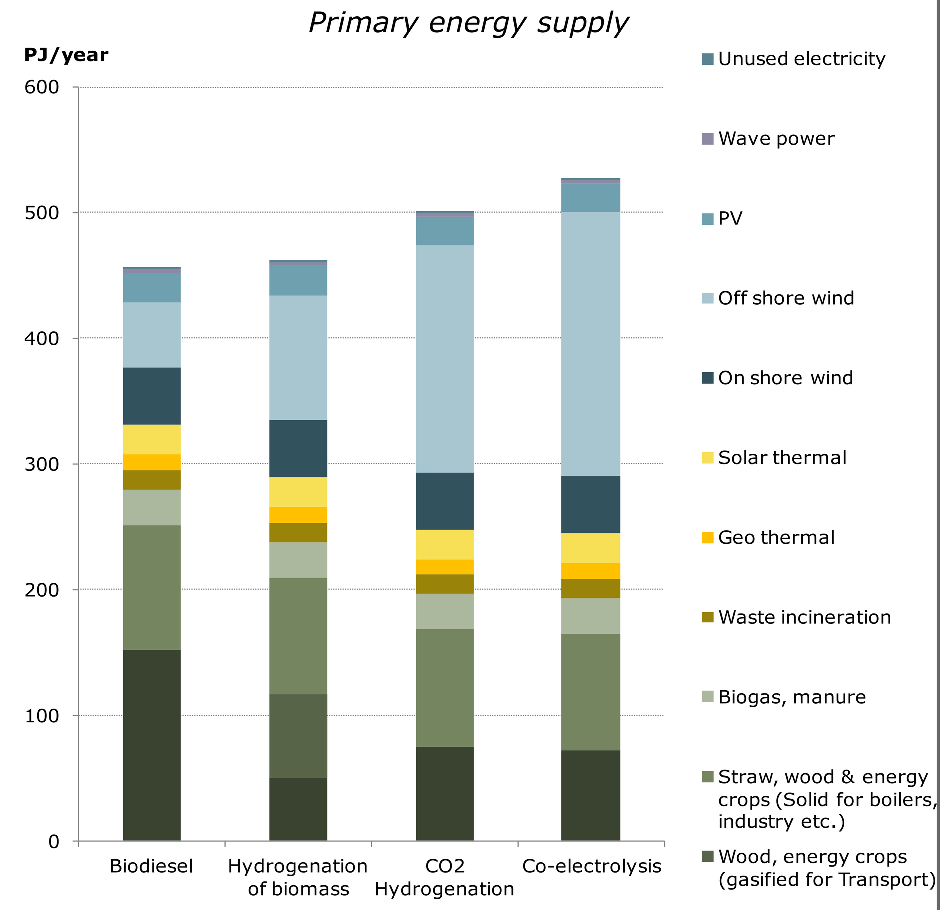
Flexibility of the system



Annual fuel/energy costs for all scenarios



Primary energy supply



Conventional biodiesel
- highest biomass demand
- least flexible
- lowest energy system costs

Hydrogenation of biomass
- the most fuel price sensitive one - highest fuel costs

Co-electrolysis* and *CO_2 hydrogenation
- most flexible alternatives, high share of wind energy
- lowest fuel consumption
- large investment costs - transport demand was met by electricity from wind turbines and electrolysers